



RESEARCH DEPARTMENT

EQUIPMENT FOR MEDIUM DISTANCE PROPAGATION TESTS IN BANDS I AND II

Report No. K-156

(1962/42)

**THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION**

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SUMMARY

This report describes receivers for the recording of the field strength of Band I television sound transmissions and Band II f.m. transmissions, together with a voltage coder and analyser for the automatic analysis of the recordings. Up to eight of these sensitive and stable receivers are mounted on a chassis, together with a loudspeaker amplifier and a common power supply unit. The outputs from the receivers are recorded on pen recorders and also on punched tape by means of the voltage coder and a tape perforator. The automatic analyser enables the punched tape to be analysed into thirty-one levels. The receivers and voltage coder use transistors throughout.

1. INTRODUCTION

Study Programme No. 140 of the 1959 Assembly of the C.C.I.R. at Los Angeles calls upon Study Group V to investigate the field strength dependence upon distance, terrain, time and frequency, of v.h.f. and u.h.f. transmissions over distances of up to 200 km.

As a contribution to this work, the B.B.C. has started to determine the propagation characteristics of transmissions in Bands I and II at various distances between 60 and 200 km from the transmitter. The fields being measured are those of existing television sound and f.m. transmissions. At the greater distances considerable fading and low signal strength will be experienced and precautions must be taken against both co-channel and adjacent channel interference. Some protection against these unwanted transmissions can be obtained by using directional aerials but most of the required protections must be obtained in the receiver.

The effect of frequency on propagation is to be studied by measuring transmissions on both Bands I and II over the same paths. Two receiving sites have been set up and up to four pairs of signals will be recorded at each receiving site. The geographical distributions of all sites and transmission paths in use are shown in Fig. 1.

Since the variations in signal level are due to tropospheric propagation conditions which vary over long periods, a large amount of recording and analysis will have to be performed. In order to reduce the amount of work involved, automatic analysers are being used in addition to the usual pen recorders. The automatic equipment takes the output of each of the eight receivers sequentially, codes an

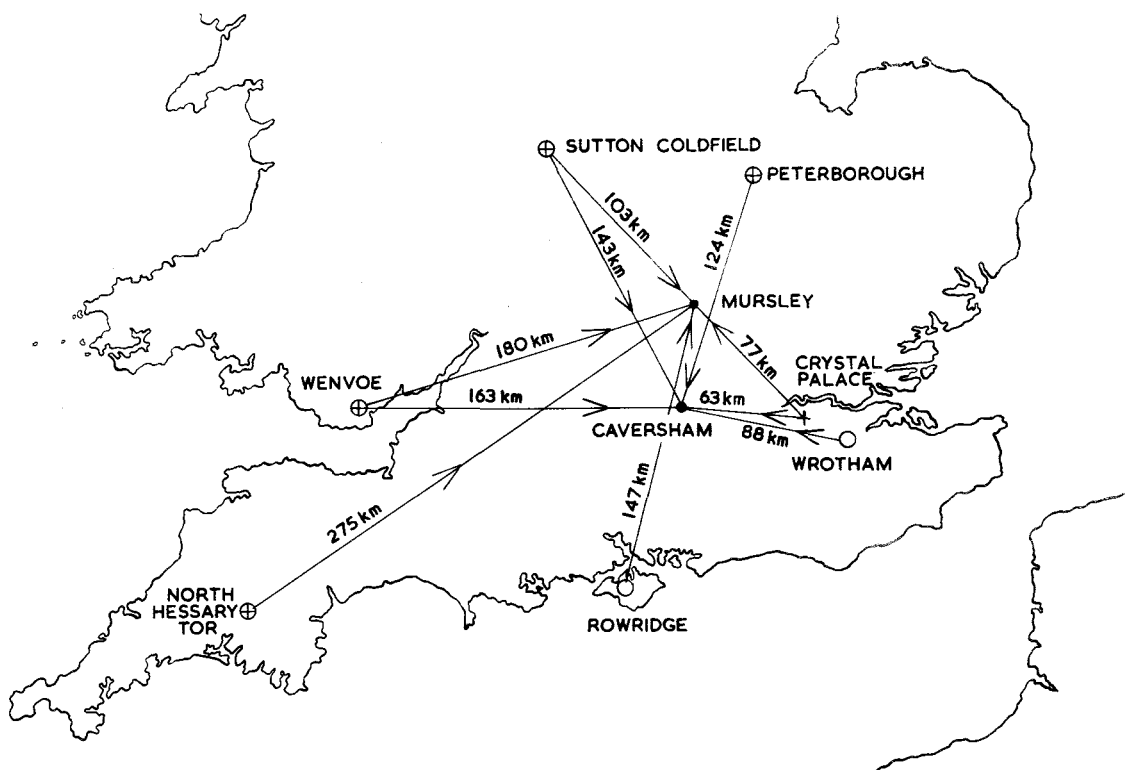


Fig. 1 - Geographical distribution of transmitter and receiver sites

- Receiving site
- + Transmitting site Band I
- Transmitting site Band II
- ⊕ Transmitting sites Bands I and II

instantaneous value of the output into one of thirty-one levels by the use of a five-figure binary code and punches the result on standard five-hole paper tape. Identification and time codes are also inserted, a complete cycle for the eight receivers taking four minutes.

When the punched tape is analysed, the analyser selects the appropriate receiver and time codes and counts the total number of times each level occurs. The analyser can deal with four different receivers and times simultaneously. The code sequences are automatically checked and a faulty code sequence will stop the analyser. From the total counts percentage time/field strength curves may be obtained.

A photograph of a complete unit of eight receivers, a coder and a tape perforator is shown in Fig. 2, while Fig. 3 is a photograph of the analyser.

2. RECEIVERS

2.1. General Requirements

The receivers are required to record the field strength of the normal programme transmissions in Bands I and II, the Band I transmissions being amplitude modulated with television sound and the Band II transmissions being frequency modulated with the Light Programme.

The receivers must operate for long periods at unattended sites with infrequent visits for maintenance and calibration. This necessitates a high standard of reliability and, in order to obtain accurate records, the gain stability should be better than ± 0.5 dB over a period of at least three months.

The median value of field strength to be recorded at any of the proposed sites is likely to be within the range +10 dB to +70 dB, reference $1 \mu\text{V/m}$, for the relevant distances and transmitter powers, and the range of fading at the greatest distances involved is expected to be of the order of 50 dB. The receivers have been designed to record this range of signal levels with a logarithmic input-output characteristic, and provision is made for adjusting the overall gain to suit the expected median signal level.

The selectivity must be such that adequate rejection is obtained of the co-channel 20 kc/s offset transmissions in the case of the Band I receivers and of the adjacent channels in Band II. The amount of rejection of these signals that had to be obtained in the receiver was specified as greater than 45 dB so as not to impose too severe a restriction upon the choice of receiving sites and directivity of aerials.

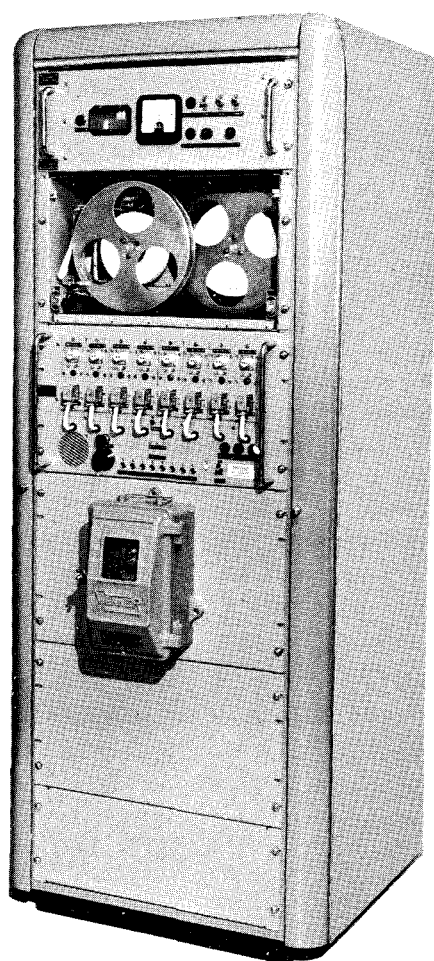


Fig. 2 - A bay of eight receivers, a coder and a tape perforator

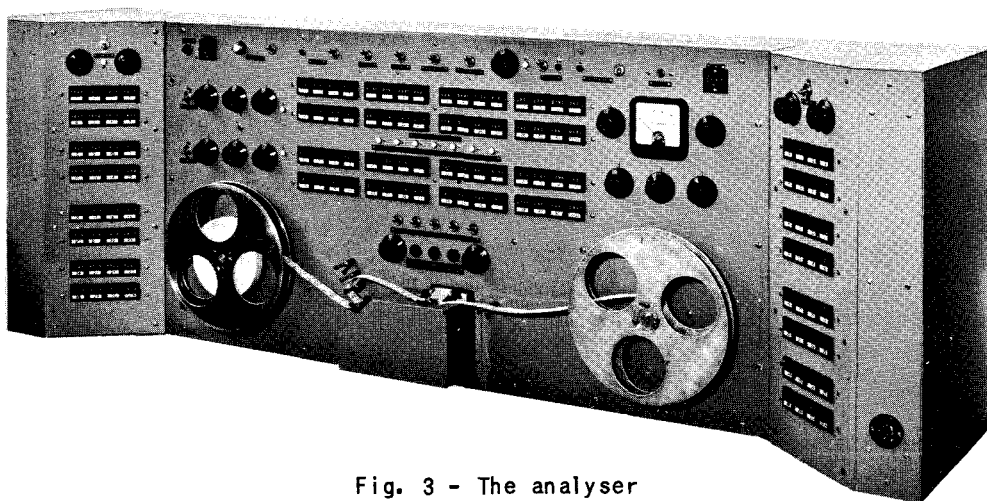


Fig. 3 - The analyser

2.2. Main Points of Receiver Design

The decision to use transistors throughout for all active components made it possible to build the eight receivers into a comparatively compact unit. The individual receivers are mounted in a temperature-controlled cabinet to obtain maximum possible gain stability although the receivers themselves are designed to operate at temperatures between -10°C and $+45^{\circ}\text{C}$ with less than ± 1 dB change in gain.

The receiver is a superheterodyne with a crystal-controlled local oscillator. The basic circuit configuration, other than the audio frequency (a.f.) circuits, is similar for both the Band I and II receivers, although different intermediate frequencies are used to simplify the problem of obtaining the specified bandwidths. The response of the receivers must be constant over a range equal to the combined frequency change of the transmitter and the receiver if the frequency drift of the local oscillator is to have no effect on the output. The maximum frequency tolerance allowed by international regulations for the transmitters concerned in the experiment is 0.003%. The intermediate frequency (i.f.) response of the Band I receivers is substantially constant over a range of ± 5 kc/s, falling by 45 dB at ± 20 kc/s. This bandwidth allows a local oscillator drift of 0.005% at the highest frequency (63.27 Mc/s) and provides sufficient rejection for the 20 kc/s offset signals. The overall frequency tolerance with temperature of the crystals used in the local oscillator is $\pm 0.002\%$.

For Band II a receiver response is specified which allows for a frequency deviation of up to ± 75 kc/s, without causing undue change in output; the bandwidth required to fulfil this objective is much greater than that arising from considerations of frequency drift. The actual response obtained is constant within ± 0.25 dB over a range of ± 40 kc/s, falls by 6 dB at ± 75 kc/s and by 50 dB at ± 200 kc/s.

A low intermediate frequency is used in order to obtain the required selectivity with the necessary stability. The problem of image frequency interference is eased by choosing the image frequency to be one at which any interfering signals likely to be present are of known amplitude.

For the Band I receivers an i.f. of 270 kc/s was chosen, with the local oscillator above the wanted frequency. The image frequency then falls within the vision frequency band of the same channel as the wanted sound carrier at 2.96 Mc/s from the vision carrier. At this frequency the amplitude of the vision sideband is normally more than 50 dB below the vision carrier level. Hence the interference from a co-channel vision transmitter will not be greater than that from the corresponding 20 kc/s offset sound signal which is attenuated 45 dB by i.f. selectivity even if no image signal rejection is provided in the receiver.

For the Band II receivers an i.f. of 2.2 Mc/s is used, this being the normal frequency spacing between the Home, Third and Light Programme transmitters at each transmitting station. The receiver local oscillator frequency is the same as that of the Third Programme transmitter and the receiver is tuned to the Light Programme. The image frequency is then that of the Home Programme transmitter and the median signal level at both wanted and image frequencies will be of the same order of amplitude. Differential fading of the two signals can cause differences in the level of the two signals of up to 30 dB and it is therefore necessary to provide 50 dB rejection of the image to reduce recording errors to negligible proportions.

The logarithmic input-output characteristic is obtained by a multiple detector type of circuit. A block diagram of this is given in Fig. 4 and the principle of operation is as follows. A detected output is obtained from each of the last four i.f. amplifier stages. Each of these outputs except the first is filtered to remove modulation frequencies and then limited at a predetermined level which is below that at which the amplifier commences to limit on peaks of modulation. This process of filtering followed by limiting avoids variations in d.c. output with changes in modulation level which would occur due to the effect of modulation peak clipping if the amplifiers were used to determine the limiting level. The first stage self-limits at a point beyond full scale deflection of the meter where peak clipping cannot affect the reading of the meter.

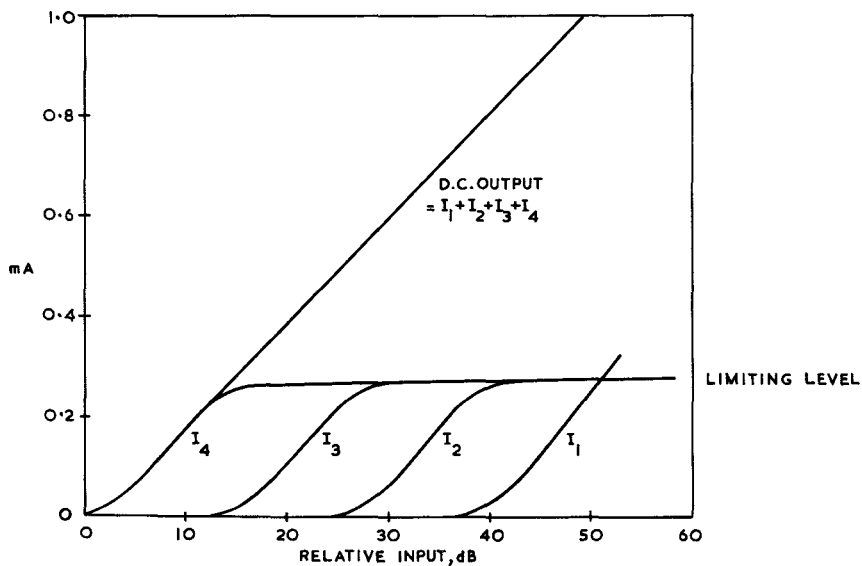
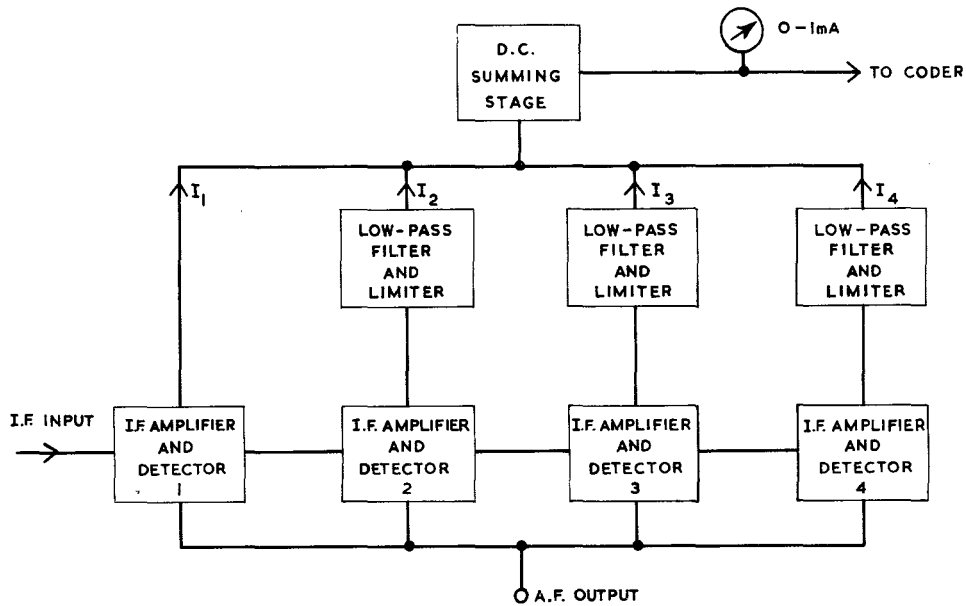


Fig. 4 - Schematic diagram of multiple detector

The outputs from the limiters are combined in a common d.c. output stage to give an overall characteristic which approximates to an ideal logarithmic law. To a first order the law is dependent only upon the stage gain and the limiting level, both of which can conveniently be stabilised. In order to avoid changes in bandwidth with changes in input level, the overall bandwidth must be determined by the stages preceding the multiple detector.

2.3. Circuit Description

2.3.1. Signal Frequency Unit

This unit is constructed on a sub-chassis which is fitted into a die-cast box attached to the i.f. amplifier unit. It contains the signal frequency (s.f.) amplifier, crystal-controlled local oscillator and balanced diode mixer. A circuit diagram is given in Fig. 5. The balanced input socket is connected via the double tuned input transformer T1 to the signal frequency amplifiers VT1, VT2. In the Band II receivers a series tuned image trap is included in the input circuit. The nominal input impedance is 72 ohms with a v.s.w.r. of better than 0.9.

The s.f. amplifiers are cascode-connected to give good isolation between input and output tuned circuits and the operating conditions of the transistors are chosen to obtain optimum stability of gain with temperature variations. The double tuned output circuit feeds the balanced mixers MR1, MR2, and the i.f. output is taken from T3 at an impedance of approximately 75 ohms. Attenuators up to a maximum value of 30 dB may be inserted between the s.f. and the i.f. unit to adjust the overall sensitivity of the receiver to suit the expected median signal.

The crystal-controlled local oscillator uses a single transistor in one of the three circuits shown in Fig. 6, depending upon the output frequency required. For frequencies below 63 Mc/s, i.e. Channels 1 to 4, a parallel resonant crystal is used in a tapped-emitter Colpitts circuit, the third harmonic output being taken from a double tuned circuit in the collector to provide adequate rejection of other harmonics. The oscillator for Channel 5 uses an overtone crystal in the feedback path from collector to emitter and the output is obtained from a tuned circuit in the collector. The tuned circuit also provides the necessary impedance transformation in the feedback loop and prevents any possibility of oscillation at the fundamental frequency of the crystal.

The Band II receivers also use overtone crystals with a resonant circuit tuned to the overtone frequency in the base of the transistor. An output at the third harmonic of the overtone frequency is obtained from a single tuned transformer in the collector. The value of the unbypassed emitter resistor R8 is low enough to prevent spurious oscillation at the frequency of the output tuned circuit.

2.3.2. Intermediate Frequency Unit

The i.f. unit is constructed on a prefabricated wiring board and with the s.f. unit and front panel forms the basic receiver unit as shown in Fig. 7. Circuit diagrams of the Band I and the Band II i.f. units are shown in Figs. 8 and 9. Except for the a.f. output, the circuit and layout is similar in both units. Mismatched common-base configuration is used in all amplifier stages with the object of obtaining

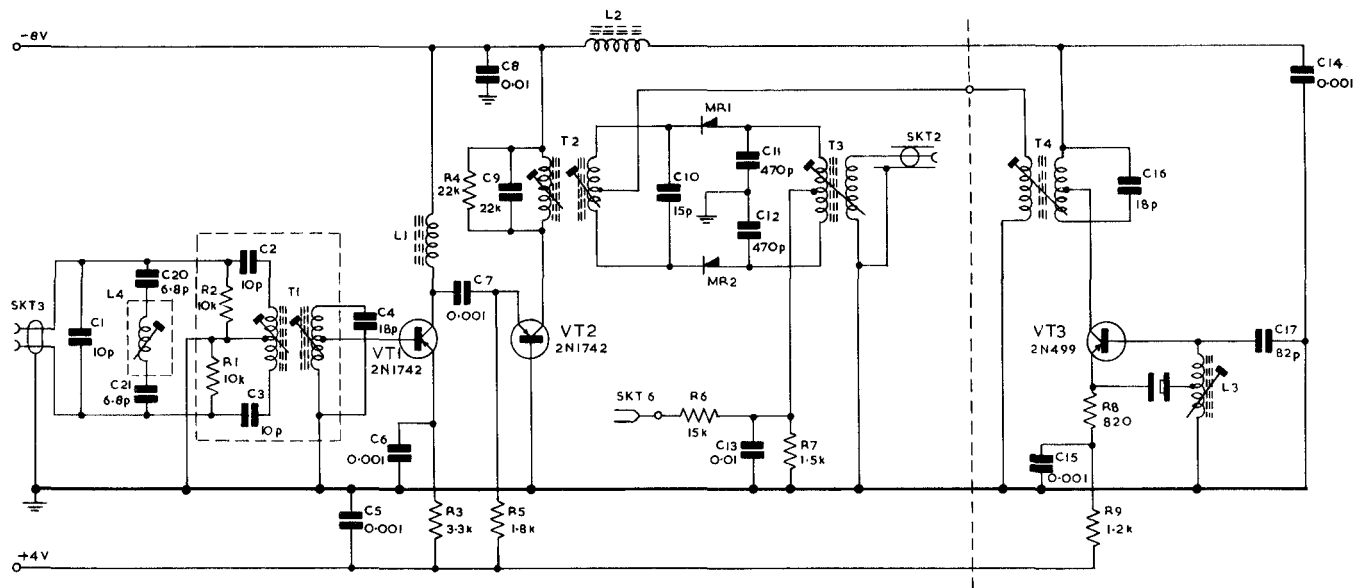


Fig. 5 - A signal frequency unit

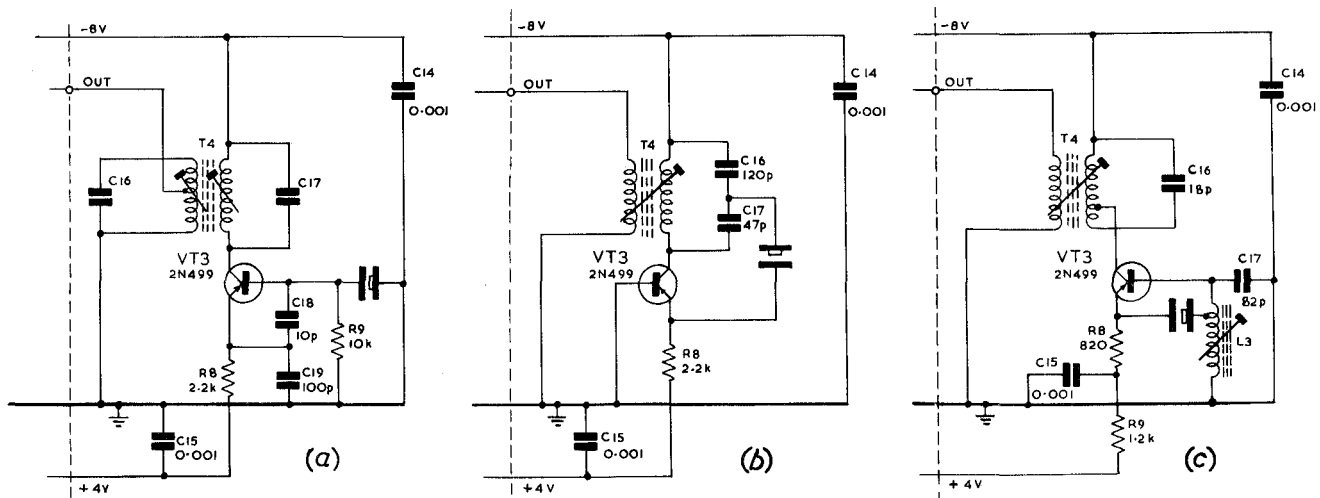


Fig. 6 - The crystal-controlled local oscillators

(a) Channels 1-4

(b) Channel 5

(c) Band II

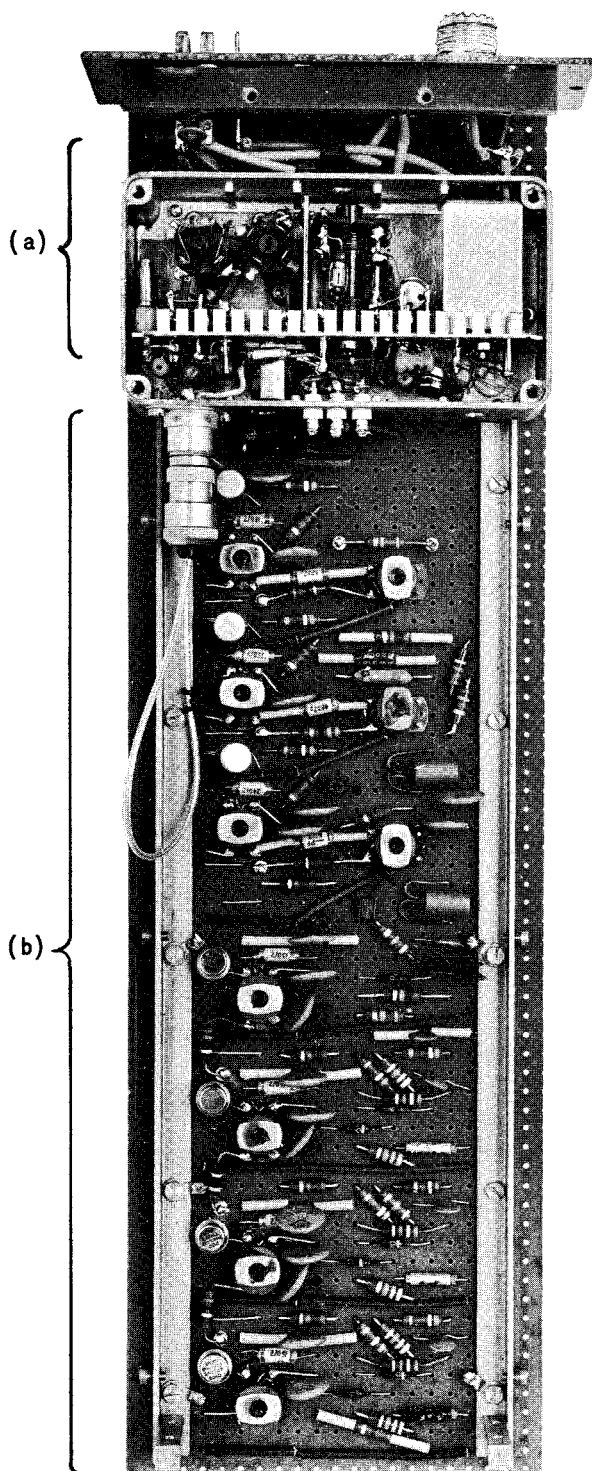


Fig. 7 - Basic receiver unit

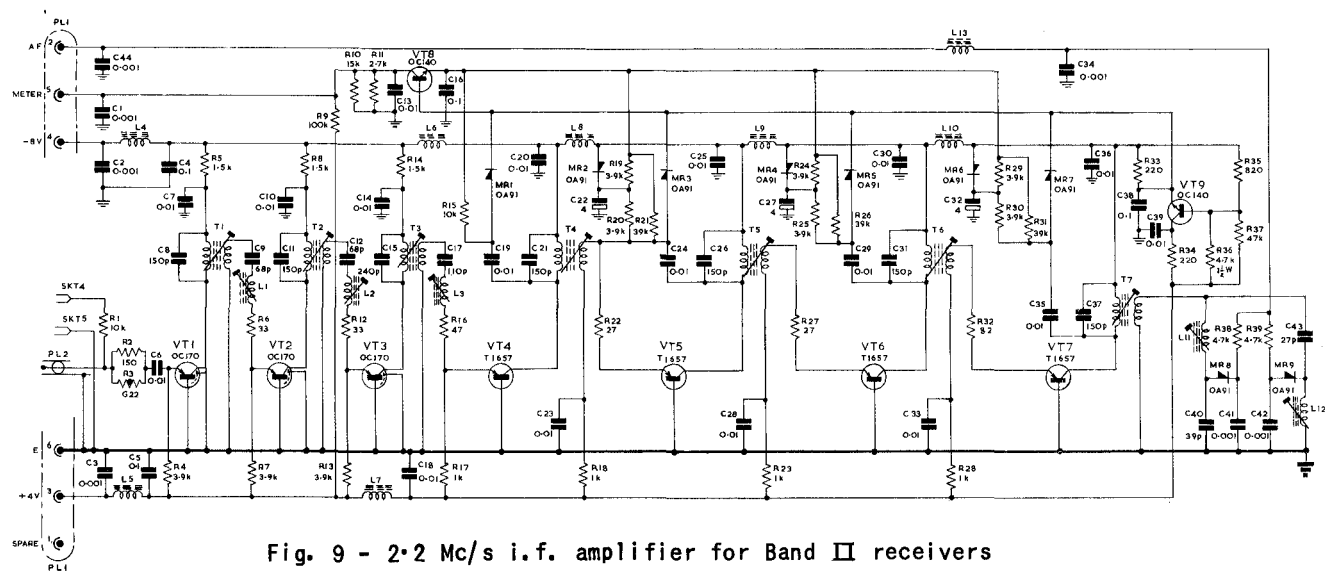
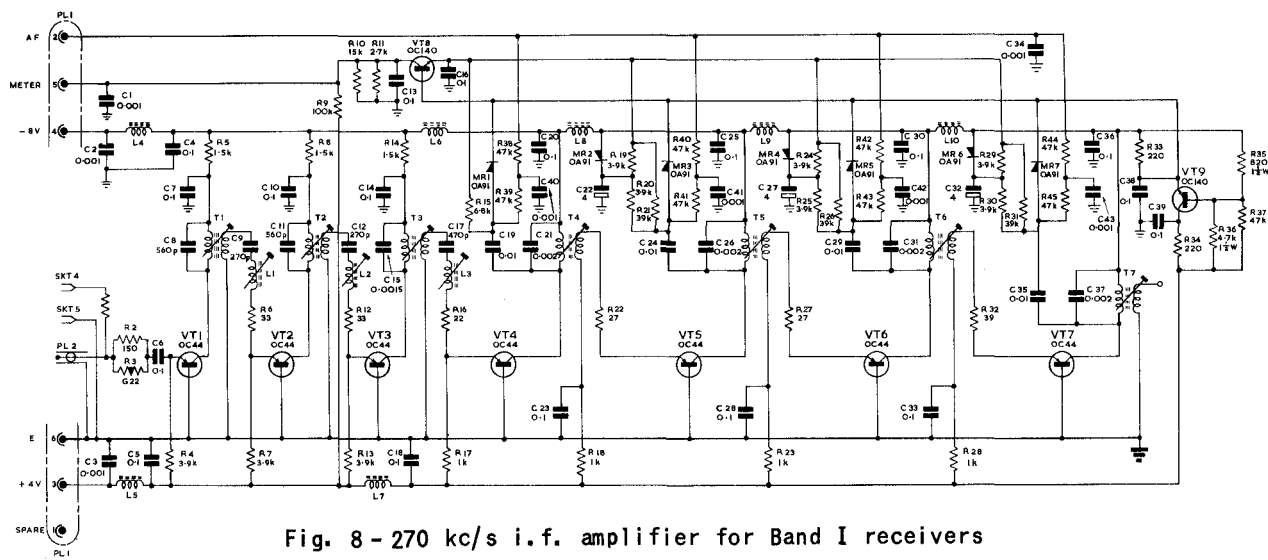
- (a) Signal frequency unit
- (b) I.F. Amplifier and detectors

good gain stability.¹ The input circuit to the first amplifier includes a thermistor R3 for compensation of the major part of any residual change in gain with temperature of the whole receiver. For test purposes an i.f. signal may be injected via R1 from a socket on the front panel of the receiver.

The filter amplifier stages VT1-3 are coupled by parallel-series double tuned circuits which, together with the single tuned mixer output circuit, determine the overall frequency response of the receiver. The resistors R6, 12, 16 in the series tuned circuits reduce the effect of any variation in transistor input impedance and provide means for making small adjustments in the shape of the frequency response characteristic of each stage during initial alignment.

The multiple detector amplifiers VT4-7 are coupled by single tuned transformers and have a gain of approximately 11.5 dB per stage. Each stage feeds a shunt detector which is connected to a low-impedance -6.4 V line fed by an emitter-follower VT9. The output from the detector amplifier VT4 is not limited, but the outputs from the other stages are applied to the limiter diodes MR2, 4 and 6 through RC networks. These diodes are connected to the -8 V supply line, so limiting each output to this voltage. The outputs are combined in a $n-p-n$ transistor VT8, which drives the 0-1 mA recording meter connected between the collector and earth.

The a.f. output in the Band I receivers is obtained by adding the output of the detectors to give an a.f. voltage which is approximately constant for different input signal levels. The audio output is distorted due to the logarithmic characteristic but is satisfactory for identification. The Band II receivers have a simple form of discriminator following the final i.f. stage.



2.3.3. Power Unit

Eight receivers are mounted in a unit which contains a common power supply and an a.f. monitoring amplifier with loudspeaker which can be switched to any of the receivers. A circuit diagram is shown in Fig. 10.

The power supply provides voltages of -8 V and $+4\text{ V}$ relative to earth. These voltages are stabilised by a series type of regulator controlled by a Zener diode MR5. The main stabilised 12 V supply is floating and a secondary regulator transistor VT4 controls the output at -8 V and $+4\text{ V}$ relative to earth.

The output voltages are constant within 1% for temperatures up to 45°C , for mains voltages between 190 V and 260 V and for load changes caused by variation of the number of receivers installed in the unit.

The receiver housing compartment is lagged with heat insulating material and contains a sealed thermostat operating at 43°C which controls the mains supply to the heating elements.

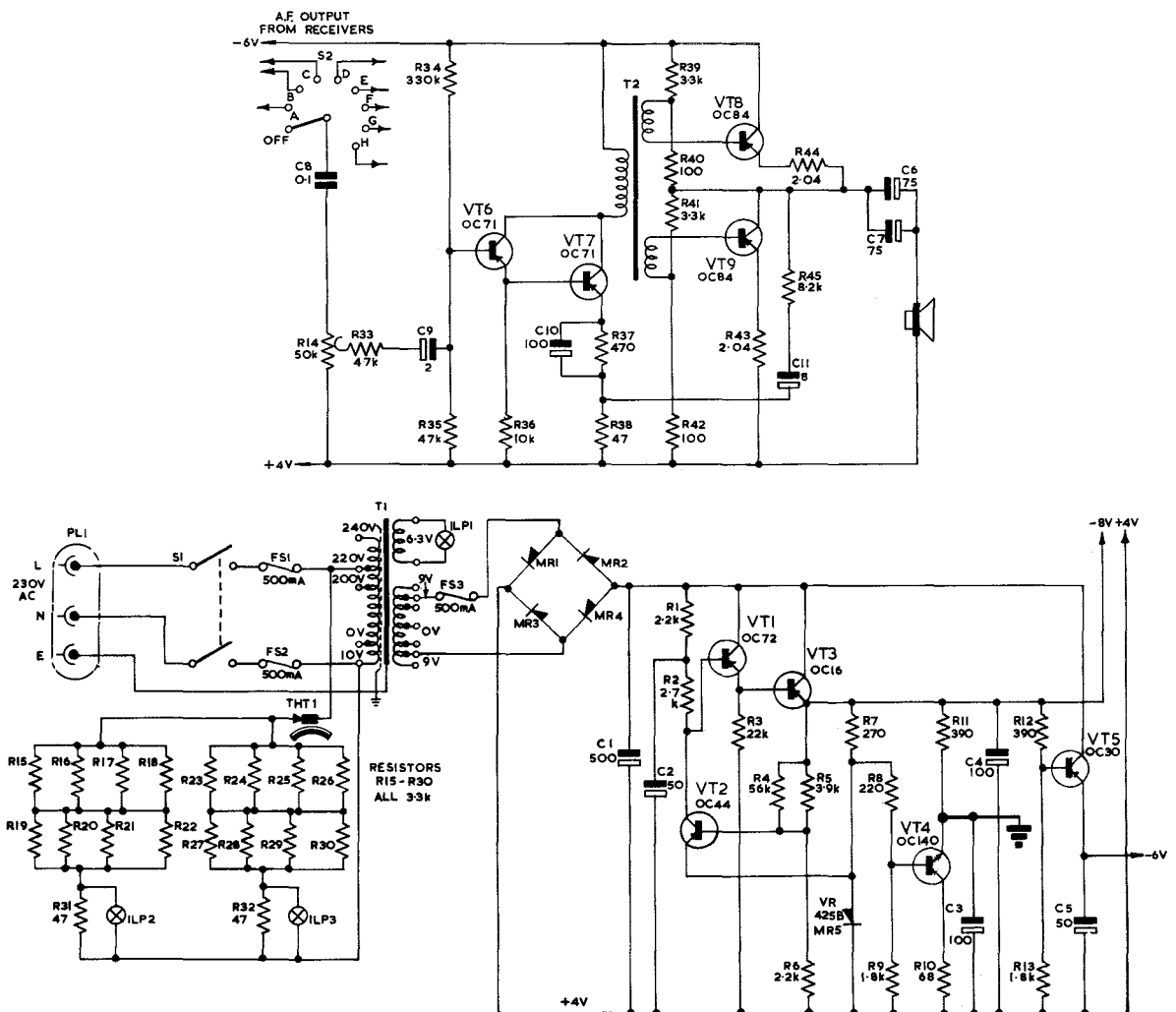


Fig. 10 - A.F. monitoring amplifier and power supply unit

2.4. Performance

2.4.1. Test Specification

The receivers have minimum performance figures indicated in the test specification below.

	Band I Receivers	Band II Receivers
Input impedance 72 ohms v.s.w.r.	> 0.9	> 0.9
Noise factor	< 10 dB	< 10 dB
Input balance ratio	> 26 dB	> 26 dB
Local oscillator voltage at aerial terminals	< 40 dB above 1 μ V	< 40 dB above 1 μ V
Image rejection	Channel 1; 8 dB Channel 5; 5 dB	> 50 dB
Overall passband response relative to centre frequency	< ± 0.25 dB to ± 5 kc/s < -45 dB at ± 20 kc/s	< ± 0.25 dB to ± 40 kc/s < -50 dB at 200 kc/s
Overall calibration	See Fig. 11	
Input e.m.f. for 0.1 mA output	2 μ V within ± 2 dB	3 μ V within ± 2 dB
Deviation from straight line characteristic	< ± 0.7 dB	< ± 0.7 dB

2.4.2. Stability

One receiver was run continuously for a period of twelve weeks and a further four receivers for one month. The calibrations of these receivers were checked periodically and were found to be within the limits of ± 0.5 dB.

Changes in receiver calibration due to variation in mains voltage are less than 0.25 dB and there is no perceptible change in the calibration of one receiver when other receivers installed in the unit are removed.

2.4.3. Spurious Responses

The frequency and magnitude of spurious responses which cause an error of 1 dB in the indicated value of a reference signal of +20 dB above 1 μ V at the wanted frequency are given overleaf.

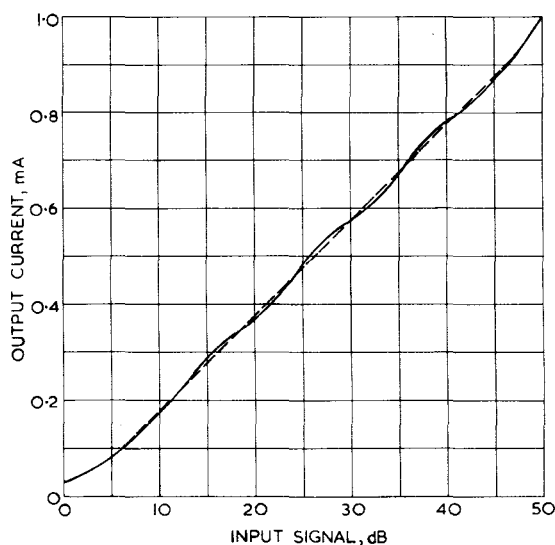


Fig. 11 - Typical calibration curve of receiver

— Typical receiver characteristic
 --- Straight line characteristic

Frequency of Spurious Signal		Input Voltage at Spurious Frequency Relative to Reference Signal +20 dB/1 μ V
Band I Receiver	$f_{osc} + f_{if}$ (image)	+6 dB
	$f_{osc} - \frac{1}{2}f_{if}$	+43
	$f_{osc} + \frac{1}{2}f_{if}$	+49
	$f_{osc} - \frac{1}{3}f_{if}$	+57
	Other responses	> +60
Band II Receiver	$f_{osc} + f_{if}$ (image)	+48
	$f_{osc} - \frac{1}{2}f_{if}$	+53
	Other responses	> +60

where f_{osc} = final oscillator frequency

f_{if} = intermediate frequency

3. THE EIGHT CHANNEL VOLTAGE CODER

3.1. General

The purpose of the eight channel voltage coder is to take the outputs of the eight receivers and code these voltages in a suitable manner for recording on a standard five-hole paper tape. In addition to the receiver outputs, signals representing the start of a receiver group, the time of day and station identification are recorded. For convenience in the analyser the various codes are split into two equal groups of six positions recorded alternately. A five figure binary code is used to record the receiver outputs. Of the thirty-two possible combinations of these five figures one, the "all blank", is used exclusively as an identification of the start of a complete group. The second position in the code group is split into three sections; the first hole is used as a time of day marker, so that the analysis may be split into daytime and evening periods. The second hole is used to identify the two groups of receivers. The other three holes are used to provide a total of seven station identification signals, each coder having a different station identification. Positions 3-6 in the group are occupied by four of the receiver output level codes, thirty-one levels being available for each receiver.

The complete sequence of two groups of six codes occupies four minutes, twenty seconds being occupied at each position. An enlarged drawing of a piece of tape showing the various codes is shown in Fig. 12.

The tape puncher unit used with the coder is a Creed Model 25X slow-speed solenoid operated reperforator.² The reperforator has been mounted on a chassis, together with a spooling motor for the tape. The chassis is fastened in the receiver cabinet on runners so that it can easily be withdrawn for maintenance.

A circuit diagram of the tape puncher unit is shown in Fig. 13 and that of the coder in Fig. 14. For convenience of description the coder will be divided into three units, the timing unit, the coding unit and the power supply unit.

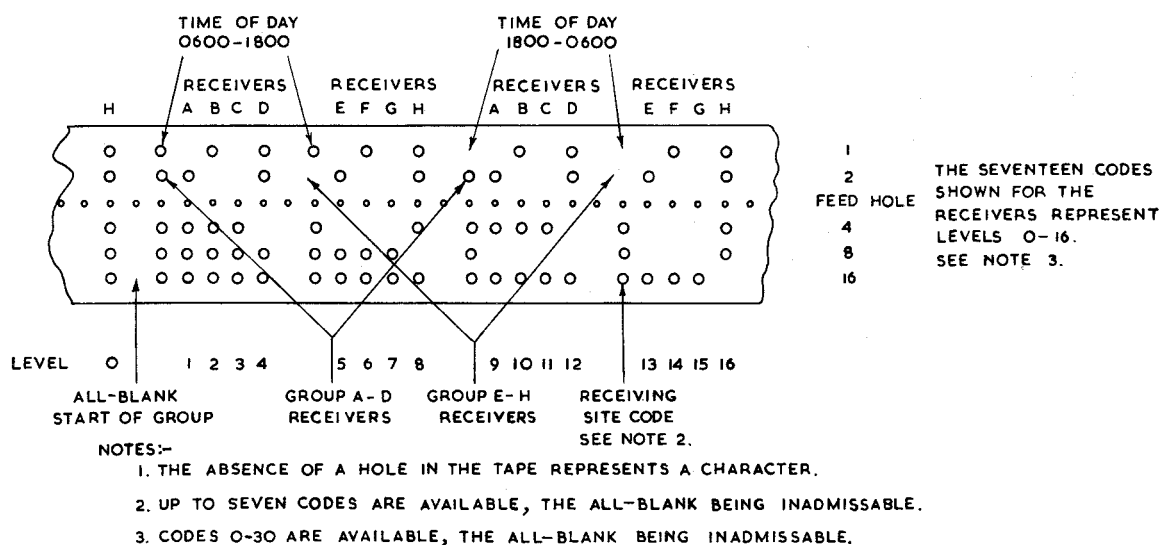


Fig. 12 - Tape showing codes used

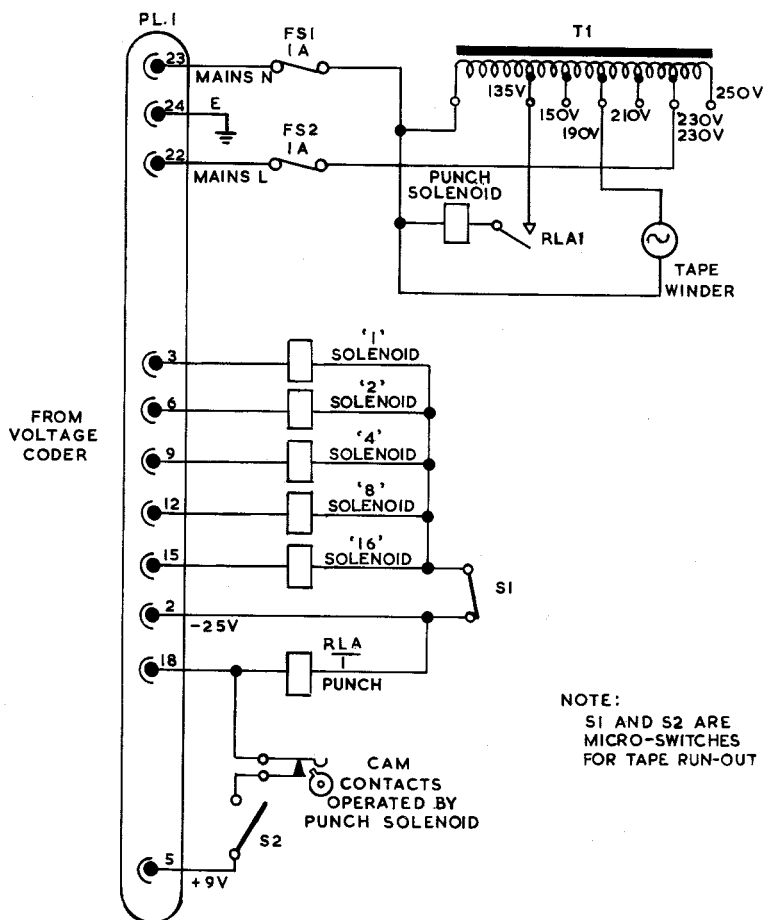


Fig. 13 - Tape puncher unit

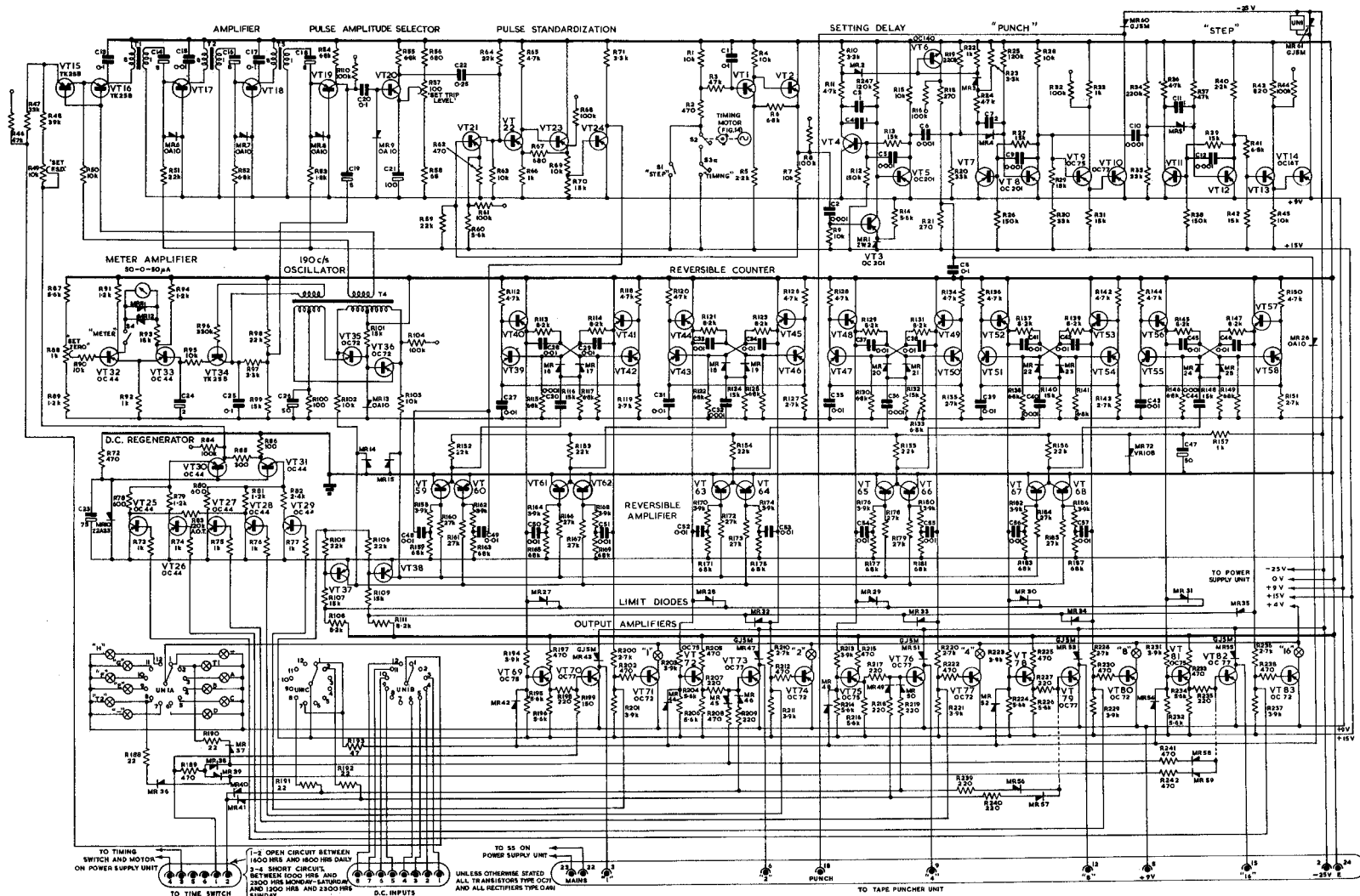


Fig. 14 - The coder

3.2. Timing Unit

The timing unit is driven by a synchronous motor and provides outputs for operating the punch relay and receiver selector uniselector at the appropriate times. A cam on the synchronous motor closes a microswitch for ten seconds once every twenty seconds to give the sequence of operations shown in Table 1.

TABLE 1

Approximate Time in Seconds	Operation
0	Microswitch released. VT2 cut off. VT21 cut off allowing code unit to operate.
10	Microswitch operates. VT1 cut off. VT2 conducts producing trigger pulse via VT3. VT21 conducts clamping code unit. VT4 conducts for approximately $\frac{1}{2}$ second dependent upon (C3 + C4) R247. VT6 unclamps code output amplifiers and sets code solenoids in tape puncher.
10.5	VT4 cut off. VT5 conducts and triggers VT7 which holds VT6 in unclamped position. VT7 conducts for approximately $\frac{1}{2}$ second dependent upon C7 R25. VT8 cut off and operates punch relay via VT9 and VT10.
11.0	VT7 cut off. VT6 clamps code output amplifiers freeing code solenoids. VT8 conducts, releases punch relay and triggers VT11. VT11 conducts for approximately 100 msec dependent upon C11 R37. VT12 cut off operating uniselector via VT13 and VT14.
11.1	VT11 cut off. VT12 conducts, releasing uniselector. Uniselector steps to next position.
20.0	Microswitch releases.

A simple low pass filter C1, R3 smooths out spurious pulses caused by any contact bounce on the cam driven switch S2. This filter is followed by a Schmitt trigger stage (VT1, VT2). The output from this stage is differentiated to provide a pulse to operate the trigger amplifier VT3. This amplifier has a delay bias of 0.6 V developed across MR1 to remove any spurious pulses from the supplies. In the ten seconds prior to this trigger pulse VT2 and VT21 are cut off, thereby permitting the coding unit (see 3.3.) to operate.

In its stable state the flip-flop (VT4, VT5) has VT5 conducting and VT4 cut off; a trigger pulse from VT3 reverses this condition for about $\frac{1}{2}$ second, the time

being dependent upon C3, C4, R247. The output from VT5 triggers a similar flip-flop (VT7, VT8). The output from VT8 is amplified by VT9 and VT10 and operates the punch relay in the tape puncher unit. The collector currents of VT4 and VT7 are applied to the base of VT6, permitting collector current to flow while either flip-flop is in its unstable condition. The output from VT6 unclamps the code output amplifiers, so allowing the code solenoids in the tape puncher unit to be set.

The output from VT8 also triggers a third flip-flop (VT11, VT12) whose amplified (VT13, VT14) output operates the receiver selector unselector solenoid.

3.3. Coding Unit

In the coding unit the d.c. output from a receiver is selected by a unselector UN1 and compared with the output from a d.c. regenerator. Any difference voltage is chopped at 190 c/s, amplified and, if it exceeds a preset bias, applied to a pulse standardisation stage. The output from this stage feeds a reversible counter which gives the binary equivalent of the input voltage. This binary output drives the d.c. regenerator and also the output amplifiers. If the unselector is on the "all blank" or "time of day" positions, the binary counter is overridden to give the required code on the output amplifiers.

3.3.1. D.C. Comparator, Amplifier and Regenerator

The receiver inputs to the unit are selected in turn by one bank UN1B of the unselector and, after subtraction of the output of the d.c. regenerator, any out-of-balance signal is interrupted by the chopper (VT15, VT16). The chopper is driven by a 190 c/s square-wave generated by the oscillator (VT35, VT36). The frequency was chosen to reduce the effects of any mains hum from the receivers. The output from the chopper will have an amplitude dependent on the out-of-balance signal and its phase will reverse with a change of polarity. This signal is amplified by the three-stage grounded base amplifier (VT17-19). Each stage is provided with base-emitter diodes (MR6-8) to reduce charging of the isolating capacitors in the event of a sudden change of input voltage. The coupling transformers are broadly tuned to the chopping frequency. The output from the amplifier is d.c. restored by the diode MR9 and applied to a biased grounded emitter stage VT20. This bias is adjustable by the "set trip level" control R57. When the amplitude exceeds this bias a pulse will pass to the Schmitt trigger circuit (VT22, VT23) unless it is blocked by the timing clamp VT21. The Schmitt trigger stage provides constant amplitude pulses for the reversible counter. These pulses may occur in either half cycle of the square-wave oscillator depending on the polarity of the out-of-balance signal.

The output of the out-of-balance amplifier before the biased amplifier is also fed to a phase detector VT34, supplied by the square-wave oscillator. The output from this detector is filtered and applied to a long-tailed pair amplifier (VT32-33) which has a centre zero meter between the collectors. This meter is used for calibrating the receivers. A bias control on VT32 provides a zero adjustment for the meter.

The reversible counter is a five-stage binary counter which supplies the inputs to the d.c. regenerator. These inputs switch the five transistors VT25-29 to the fully conducting or cut off condition. The collector currents of these transistors pass to the emitters of the grounded base summing amplifiers VT30, VT31. Since the bases of these summing amplifiers are fed from a stabilised supply via the

drive transistors (VT25-29) the current inputs to the summing amplifiers will be inversely proportional to the collector loads (R78-82) of the drive stages. These loads are arranged in a binary series so that the currents into the summing amplifiers will be of binary form. In order to reduce the range of these currents, VT25, VT26 have their collector load resistances increased four times, thus reducing the currents to one quarter. To compensate for this, the summing amplifier VT30 has a collector load resistance of four times that of the other summing amplifier (VT31). Since in a grounded-base stage the collector current is almost equal to the emitter current and is also almost independent of collector voltage, the final collector voltage will represent the sum of the outputs of the binary counter. This output is used to balance the inputs from the receivers. A preset control (R49 Set F.S.D.) is provided to adjust this balance.

3.3.2. Reversible Counter

In the binary system of Table 2 it will be seen that for both forward and reverse counting the least significant digit is reversed for every count. For the higher significant digits, the digit reverses when the next lower significant digit changes from 1 to 0 for a forward count and from 0 to 1 for a reverse count.

In this reversible counter five Eccles-Jordan multivibrator stages VT39-58 are cascaded, with gating circuits between each. The gating circuit consists of two grounded-emitter amplifiers VT61-62, etc., which have a common output driving the following multivibrator stage. The bases of the amplifiers are alternately fully cut off by the 190 c/s square-wave oscillator or become almost conducting. Further, pulses from the preceding multivibrator provide separate feeds to the base of each of the transistors VT61-62, etc. Now if the pulse coincides with that part of the cycle of the 190 c/s square wave which makes the base of the amplifier almost conducting, an output will be obtained for driving the following stage. Since the time of the input pulse varies, relatively to the 190 c/s square wave, according to whether an addition or subtraction is required and since the direction of the count is reversed every half cycle, the input pulse will change the counter in the required direction.

TABLE 2
A Binary System

Number	Binary Number	
0	0000	
1	0001	Forward
2	0010	↓
3	0011	
4	0100	
5	0101	↑
6	0110	
7	0111	Reverse
8	1000	

In order to prevent the counter from stepping below zero or above 30, two sets of diodes MR27-35 are used which permit either VT37 or VT38 to conduct if all the counters are in the same direction. The transistors VT37, VT38 then block the input square wave to the appropriate reversing amplifiers and prevent further counts in that direction. Reversing amplifiers VT59, VT60 are placed in the input pulse circuit to remove the drive to the first counter when this block is applied. No other reversing is performed by this particular pair of amplifiers.

Each of the multivibrators is provided with two emitter-follower outputs VT40, VT41, etc.; one output feeds a two-stage amplifier VT69, VT70, etc., which drives the code solenoids, and the other supplies the d.c. regeneration amplifier and emitter followers VT71, etc., which operate dial lamps to indicate the position of the count. The first stages of these amplifiers, VT69, etc., are held beyond cut-off except when released by the combined outputs of the code and punch solenoid delay circuits VT6 (see 3.2.). They are also held beyond cut-off by a voltage obtained via the uniselector bank UN1C during the "all blank" punch period which occurs every sixth punch. The second punch of each group of six is in three parts. The "1" code output amplifier VT70 is held either conducting or cut off by a suitable potential to the base of this transistor, the polarity being determined by the time switch. The "2" code output amplifier VT73 is held conducting or cut off alternately by potentials selected by the uniselector. The "4" and "8" code output amplifiers VT76, VT79 are held beyond cut-off and the "16" amplifier VT82 is maintained conducting by similar potentials obtained from the uniselector. The precise arrangement of the potentials to these three stages may be varied to give a different station identification. The different amplifiers are isolated by diodes MR45-51, etc.

All solenoids are fitted with overswing diodes type GJ5M to protect the driving transistors when the current to the solenoids is interrupted.

3.4. Power Supplies

The power unit (Fig. 15) provides stabilised outputs at +4, +9, +15 V and an

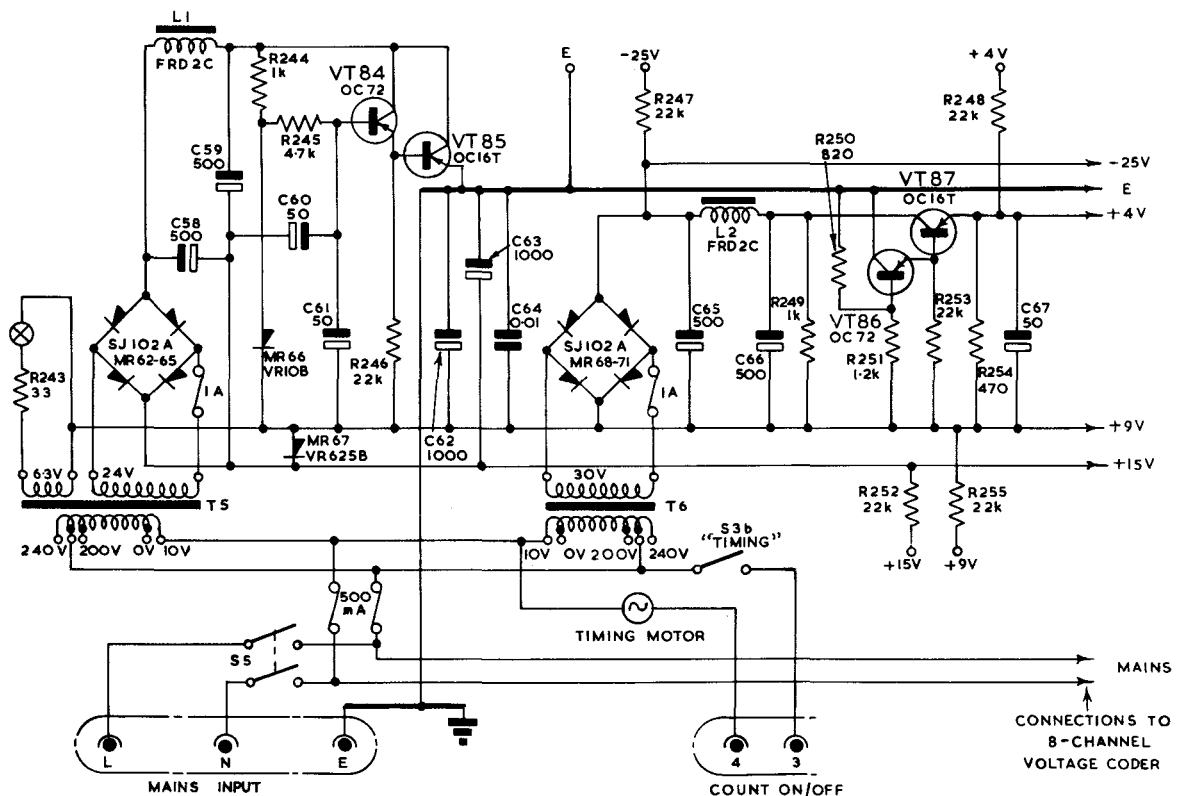


Fig. 15 - Coder power supply unit

unstabilised output of -25 V. The supplies are stabilised by Zener diodes MR66, MR67 with emitter follower outputs VT84-87 where required.

4. THE THIRTY-ONE LEVEL ANALYSER

4.1. General

This analyser accepts punched tape produced by the voltage coder, selects appropriate signals for a specified time of day from individual receiver channels and counts the number of times each level has been recorded. Four channel and time of day combinations can be dealt with simultaneously. A circuit which may be switched to any channel is provided for reconstituting the signal in suitable form for application to a recording milliammeter.

Switches are provided to simulate the operation of the tape reader for slow speed testing. Tapes comprising one, three, four, five or six units of five holes may be analysed.

When the medium-distance recording receiver tapes are analysed, two groups of six units are used for coding the results from eight receivers. Each group is identified by using spare time of day codes since only two of these are required for timing (see Fig. 12).

4.2. The Tape Reader

The tape reader is a Creed S3672M transmitter head³ driven by a 390 r.p.m. induction motor. The head has a non-standard timing sequence and parallel operation of the signal contacts. The timing sequence is shown in Fig. 16. Twenty-four milliseconds after the start of a reading cycle cam D allows the signal contacts D1-D5 to close if an appropriate hole has been punched in the tape and they remain closed for 100 milliseconds. Sixty milliseconds after the start cam E contacts close, thereby energising the counters and the unselector coil. The unselector wipers do not move until the coil is de-energised 60 milliseconds later. Cam C operates 110 milliseconds after the start to allow the "tape-out" contacts to open for 20 milliseconds if there is no tape in the reading head.

4.3. The Analyser Circuit

A complete circuit diagram of the analyser is shown in Fig. 17.

If the "tape drive on" switch S28 is operated after the analyser has been switched on with the systems switch S24 in the analyse position, mains is

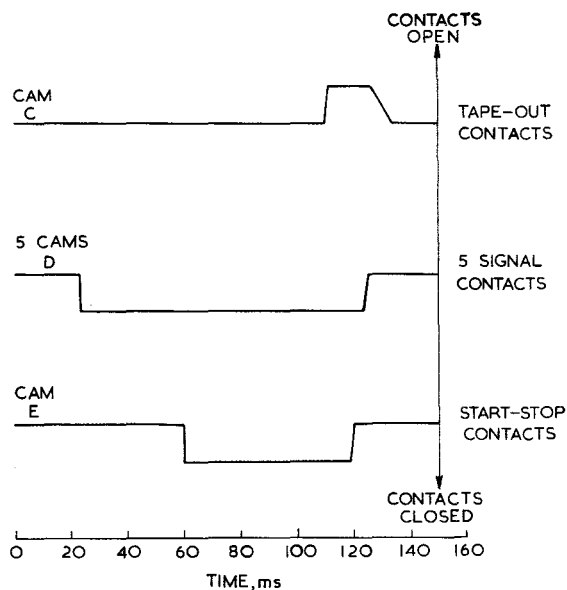


Fig. 16 - Timing sequence of tape reader

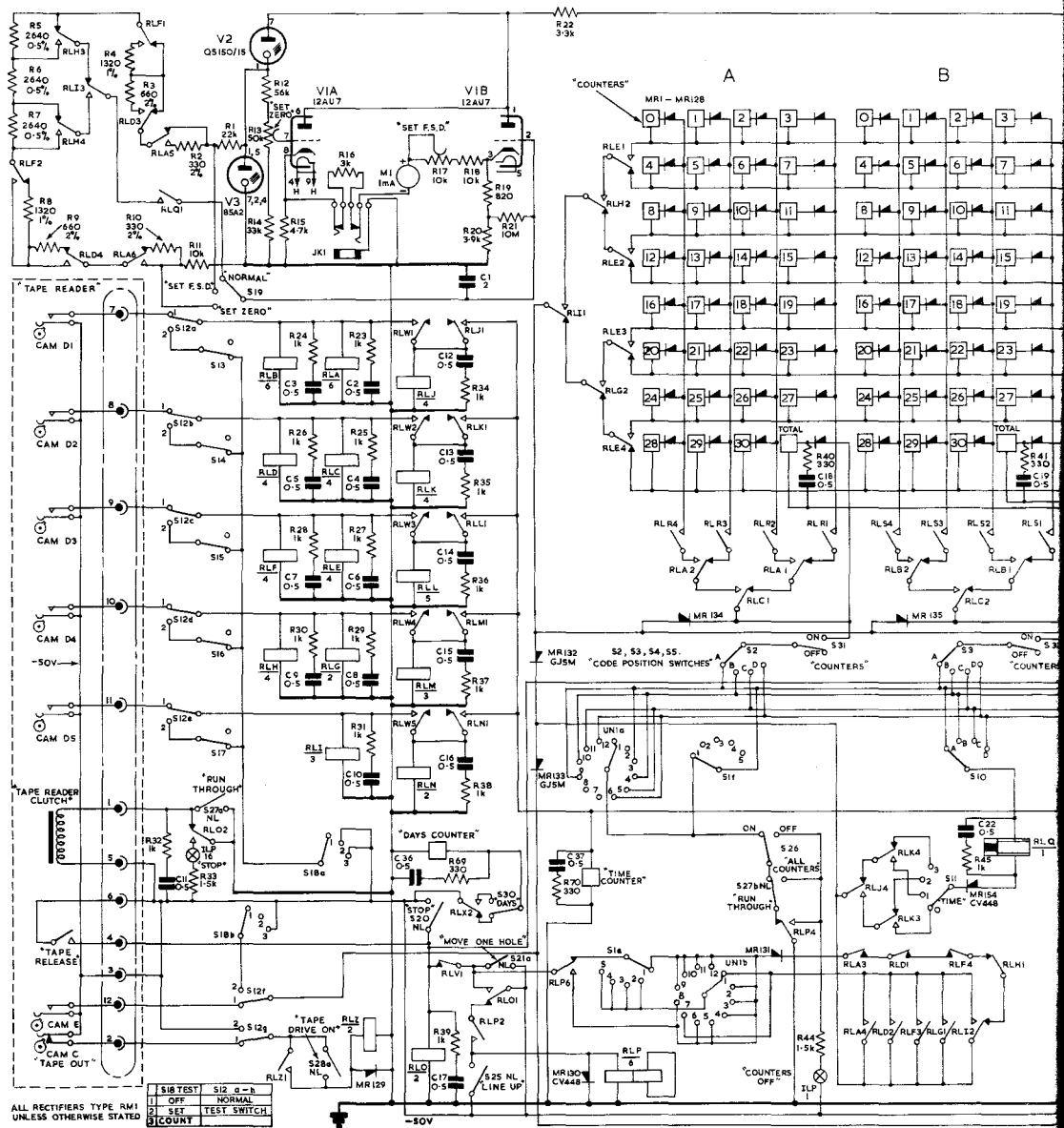
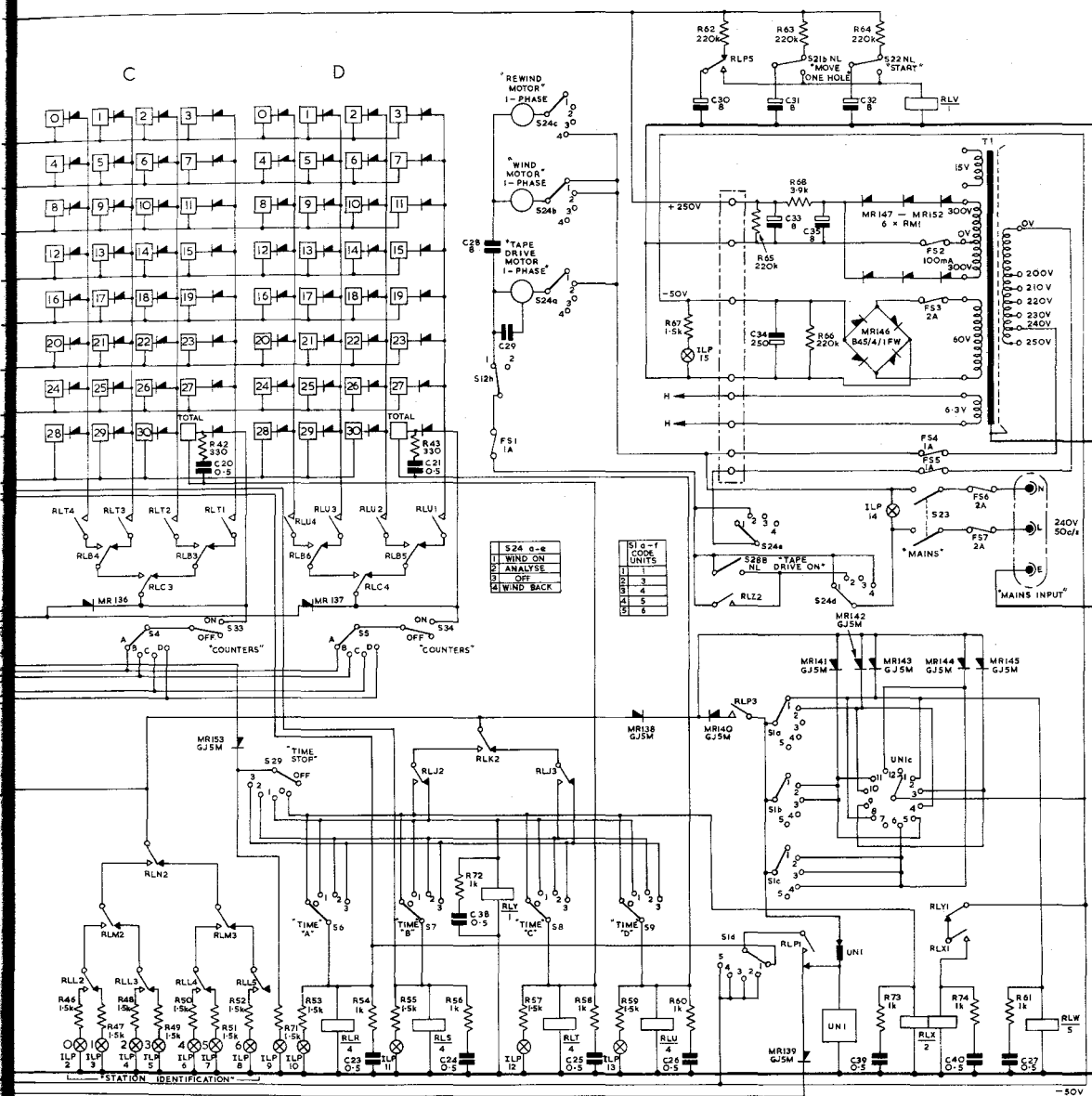


Fig. 17 - The analyser



applied to the power unit, the tape drive and wind motors and 50V via cam C contacts to relay Z. This relay locks in, thereby maintaining the mains supply, provided the "tape-out" cam C contacts had not previously operated. These contacts can be reset by depressing the tape release, which is mechanically interlocked with the tape out contacts. The analyser will now start; normally, however, the tape will not be aligned and will stop almost immediately, due to relay O operating for an error, as is explained later.

Closing the "line-up" switch S25 operates relay P. This relay disconnects the counters via RLP4 and causes a capacitor C30 to discharge into relay V via RLP5. The momentary operation of relay V breaks the supply to the stop relay O via its maintaining contact RLO1. The release of relay O locks relay P on via RLO1 and RLP2. The tape reader clutch is also operated by RLO2. A 50 V supply is applied to the unselector through UN1c, MR140-145 and RLP3, enabling the unselector UN1 to step at high speed until an "all blank" position (positions 1 and 7 on UN1c) is reached; the unselector then stops. The tape reader operates until an "all blank" code occurs, when a supply is provided for relay O via cam E, MR133, RLI2, RLH1, RLF4, RLD1; RLA3, MR131, RLP6 and RLV1. This stops the reader, locks on relay O (RLO1) and releases relay P.

On the release of relay P the unselector is stepped one position by a pulse from the tape reader cam E via MR139 and RLP1. This completes the alignment of the tape and analyser. On code 1 the line-up is not used.

On pressing the start switch S22, relay V operates, releases relay O and energises the tape reader clutch. The analysis commences and will continue until the tape runs out or a fault is found. When the unselector is stepped to the "all blank" positions (UN1 position 1 and 7) relays J-N are released by UN1c. In the time of day position (UN1 positions 2 and 8) relay W operates. Twenty-four milliseconds after the start of a reading cycle cam D allows the signal contacts D1-D5 to close if an appropriate hole is present in the tape. These contacts allow relays A-N to operate, relays J-N operate only in the time of day position, locking on via RLJ1, etc., MR138, MR141-145 and UN1c. Thirty-six milliseconds later cam E closes, stepping the unselector UN1 via MR139, RLP1, thus releasing relay W. This prevents any further operation of relays J-N. Relays L-N select the "station identification" lamps whilst relays J and K provide the inputs for the time of day selection switches S6-9, 11. Relays R-U operate when the selected time of day occurs. The unselector releases 120 milliseconds after the start of the cycle (cam E) and the signal contacts (cam D) after 125 milliseconds.

The unselector switch UN1a in conjunction with the "code position" switches S2-5 and 10 enable code positions to be selected for the counter banks. When one "code position" has been selected together with a "time of day" the signal relays A-I will select the appropriate level counter and one will be added to its total by a pulse from the cam E contacts. One is also added to the "total" counter for that bank when the time of day selection occurs. Thus a check on the total and the sum of the separate counters will reveal any faulty operation of the signal relay contacts or counters. At the end of the "all blank" period UN1c releases the time of day and station identification relays and operates relay W, allowing a fresh code to be set up for the next cycle.

If code 1 is used counter bank A is permanently selected and the uniselector switched out of operation.

If codes 3, 4, 5 are used then after the signal code positions the uniselector will advance to the "all blank" position automatically via UN1c and Sla-c. A continuous monitor on the tape alignment or faults in the punching sequence is given by the signal relay contacts RLA3 and 4, RLD1 and 2, RLF3 and 4, RLG1, RLH1, RLI2 in conjunction with the uniselector UN1b and the code switch Sle. These contacts operate the stop relay O if either an "all blank" occurs in a signal period or a signal in an "all blank" period.

In order to assist in finding a particular time and day during the analysis two re-settable counters are provided, together with a switchable "time stop" S29. When any time of day code selected by the "time stop" switch occurs, relay O will operate and stop the analysis. This enables the "time" counter to be re-set at the start of a particular time period. The "time" counter is operated by the output of the uniselector UN1c MR141-145 and MR138 and counts the number of code groups. The outputs of the time of day selection contacts RLK2, RLJ2 operate relay X on time "O" and relay Y on time "1". Relay X locks on when operated and is released by operation of relay Y. A re-settable "days" counter is operated by relay X and will count 1 for each change from time "O" to time "1", an occurrence which happens once per day on the tape. A push button S30 is provided to set up an initial date.

Switches are provided to enable the counter banks to be switched off either individually by S31-34 or collectively by S26. Switches are also provided, S21 to enable the tape to be advanced one hole, S27 to enable the tape to be run through, and S20 to stop the analysis.

Relay Q operates as selected by the code and time switches S10, 11 and enables a voltage dependent on the signal to be switched to the metering amplifier V1. This is a pair of cathode followers with the output for a recording milliammeter taken from between the cathodes. This circuit enables a pen record to be made of one of the signal inputs and is helpful in finding certain changes of input signal such as receiver or transmitter failure, etc. If the tape runs out, cam C contacts open at the end of the reading cycle to release relay Z, which disconnects the whole analyser from the mains via RLZ2.

In order to facilitate fault finding, a test switch S12 replaces the tape reader cams D and E by switches S13-18, thus allowing all steps to be checked at leisure. All coils are provided with either rectifier or CR spark suppressors. Facilities are provided by switch S24 for winding on and rewinding the tape.

Comprehensive test tapes have been prepared which operate all components of the analyser and enable a check to be made on all operations in turn.

5. CONCLUSIONS

The receivers and coder described in this report have been operating on an unattended basis for several months. Weekly checks on the coder and the calibration of the receivers have been carried out. Apart from one minor failure the performance of the equipment has been entirely satisfactory.

The analyser, however, performed satisfactorily at the start but erratic performance of some of the relays has been a source of trouble. This failure is being investigated.

With the object of using computer services for analysis, programming tape has now been developed and it is proposed that all future tapes should be analysed by this means.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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